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Third instar of the myrmecophilous *Italochrysa insignis* (Walker) from Australia (Neuroptera: Chrysopidae: Belonopterygini)

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We dedicate this paper to Professor Maria Matilde Principi, University of Bologna, in recognition of her exemplary studies of *Italochrysa* biology and morphology.

Abstract

The third instar of the Australian green lacewing *Italochrysa insignis* (Walker) is described and compared with that of the European *Italochrysa italica* (Rossi). Larvae of both species are associated with arboreal ant nests. Moreover, they share a substantial number of morphological adaptations that may defend them against ants and that distinguish them from larvae of other chrysopids. The larvae of the two *Italochrysa* Principi species also have distinct differences. The potential systematic value of several of the larval characters at the tribal, generic, and species levels is assessed, and a brief review of myrmecophily in the Belonopterygini is presented.

Key words: Chrysopinae, larval morphology, debris-carrying, defense

Introduction

Italochrysa Principi, with ~75 described species, is the largest and most widespread genus in the green lacewing tribe Belonopterygini (Neuroptera: Chrysopidae) (Brooks 1984, Brooks & Barnard 1990, Hölzel & Ohm 2003, Oswald 2007). It occurs throughout much of the Old World, particularly in tropical and subtropical regions.

Despite the broad geographic distribution of the genus, information on the biology and immature stages of its numerous species is scarce. The first instars of two species were described and illustrated [*Italochrysa insignis* (Walker) from Australia (New 1983) and *Italochrysa stigmatica* (Rambur) from Spain (Díaz-Aranda & Monserrat 1995, Monserrat & Díaz-Aranda 2012)]. Also, images of first instar *Italochrysa italica* (Rossi), previously posted on the internet, are reproduced here (courtesy of C. F. Cesaroni & R. A. Pantaleoni). Despite several attempts, rearing of neonates has proven unsuccessful (New 1983, 1986, Tsukaguchi 1995).

Italochrysa third instars are known for only one species; detailed observations and descriptions of *I. italica* documented a larval association with ant colonies (Principi 1943, 1946, as *Nothochrysa*). The larvae were observed to prey on ant brood, and their specialized debris-carrying behavior was found to provide them a high degree of protection from worker ants. Also, Principi identified many morphological and biological modifications of *I. italica* that previously were unknown from chrysopid larvae and that presumably are related to predation on ant brood. Her findings provide an excellent basis for comparison with other *Italochrysa* species and belonopterygines in general.

Unfortunately, analogous information from other belonopterygine species is very scanty (See Tauber *et al.* 2014). The behavior and morphology of *Nacarina valida* (Erichson) [second or third instar = Semaphorant B, as *Nadiva* Navás] were briefly described and illustrated by Weber (1942). In addition, the first instars in only two other genera have been described, i.e., *Calochrysa extranea* (Esben-Petersen) by New (1986) and *Vieira elegans* (Burmeister) by Tauber et al. (2006, transferred from Leucochrysini). As a result of the limited data, the larval features that distinguish belonopterygine genera and, indeed the tribe, have not been firmly established.

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Herein, we describe and figure the third instar of *Italochrysa insignis* (Walker) collected from an ant nest in Australia. The larval morphology of this species is compared with Principi's (1946) description of *I. italica*, and the systematic implications of these findings are discussed.

Materials and Methods

Two third instars were collected under the bark of a *Eucalyptus* tree in the nest of the formicid *Technomyrmex jocosus* Forel. Both specimens were collected alive and with miscroscopic examination were confirmed as conspecific. One specimen was held in a small rearing container along with adults and brood of *Technomyrmex* ants from the same nest until the larva spun a cocoon. A female adult (Fig. 1) emerged, and the specimen was preserved and used to identify the species. The second larval specimen was preserved and stored in 95% ethyl alcohol. This specimen was photographed, its external gross features were noted, and then it was cleared in KOH and transferred to glycerine for description of fine structures and setation. For morphological terminology and chaetotaxy, we followed the usage of Rousset (1966), Tsukaguchi (1995), Tauber et al. (2006), and Monserrat & Diáz-Aranda (2012).

FIGURE 1. *Italochrysa insignis,* adult (Brisbane, Queensland, reared from larva collected in a nest of *Technomyrmex jocosus* Forel). (Photo, SLW)

Results

***Italochrysa insignis* (Walker).** Collection data: AUSTRALIA: Queensland: Brisbane, Slaughter Falls [-27.476200°, 152.963972°], March 2007; S. L. Winterton, two late instars from the nursery chamber of a nest of *Technomyrmex jocosus* Forel, under bark of *Eucalyptus* tree. Both the larva and adult are deposited in the California State Collection of Arthropods (CSCA), Sacramento, California.

Description of third instar. *Body* (Figs 2A–D) stocky, compact, relatively flat ventrally, highly globose dorsally, length ~5.8 mm (measured in lateral view through spiracles), depth ~2.1 mm (thickest section of abdomen). Thoracic, abdominal nota remarkably wide, extending fully over sides of larva, with lateral tubercles extending laterally from ventral margins of nota. Integument largely cream-colored to tan, with pronotal plate, sclerites, setal bases largely brown. Setae of three main types, defined here as: smooth-hooked = erect, with smooth surface, hooked tip, usually tan colored [dorsum of thorax, abdomen, including dorsum of lateral tubercles (LTs)];

denticulate = stout, with rough surface, blunt tip, brown to cream-colored [straight or gently curved: primary cephalic setae, most setae on cephalic appendages, some setae (LS) on abdominal LTs; with distal 1/3rd to 1/4th bent or curved perpendicularly: setae on tips of thoracic LTs]; simple = small, smooth surface, acute tip, usually erect or slightly curved.

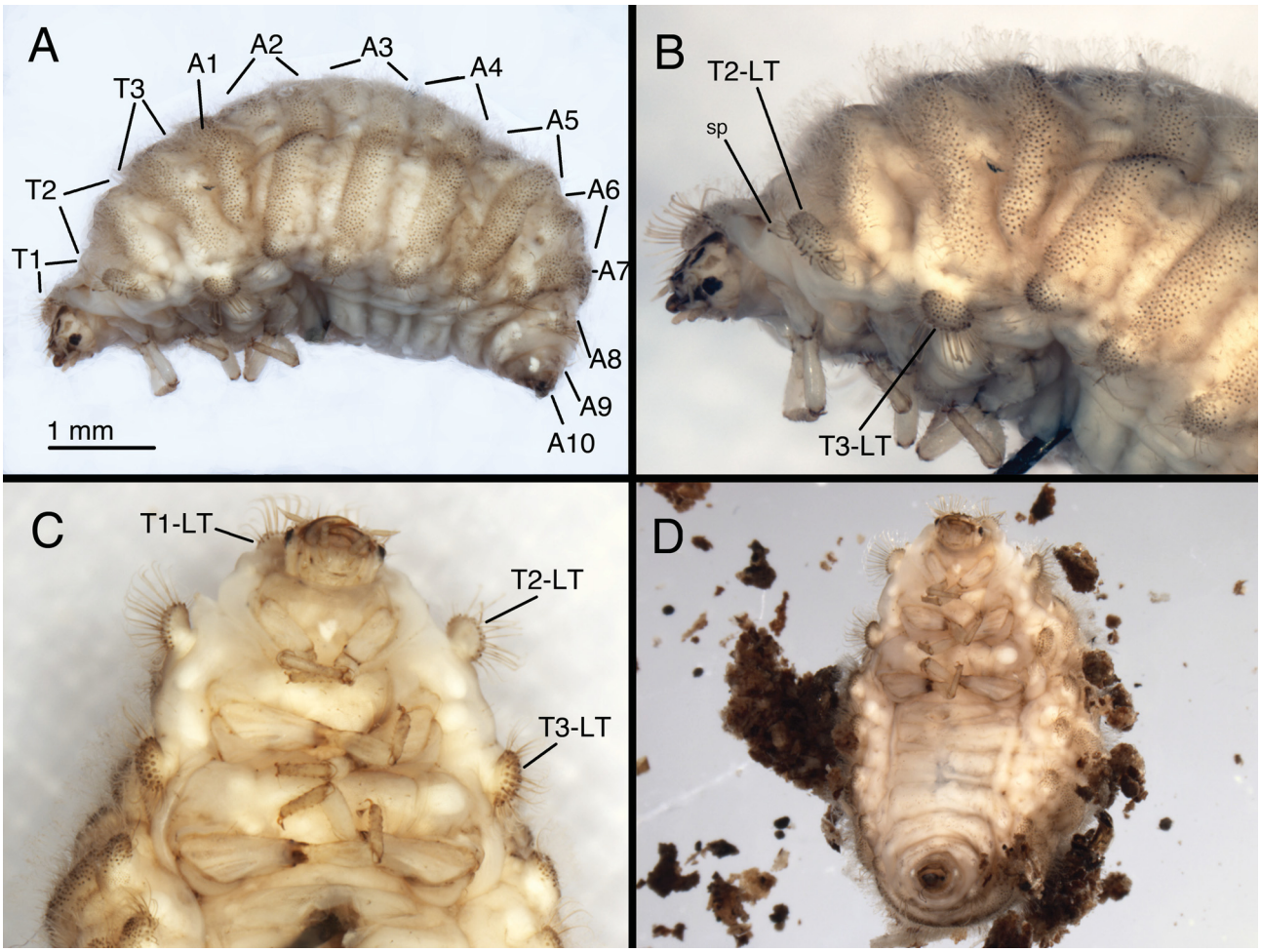

FIGURE 2. *Italochrysa insignis,* third instar (Brisbane, Queensland). A. Body, lateral; B. Head and thorax, lateral; C. Head and thorax, ventral; D. Body, ventral (with debris). Abbreviations: Ax, abdominal segment number; sp, spiracle, Tx-LT; number of thoracic segment—lateral tubercle. (Photos, CAT)

Head (Figs 3A–F, 4A, 4B) cream-colored, with brown to dark brown markings as in Figs 3A, 3D, 4A (dorsal); 3B, 3C (lateral); 3F (ventral); cranium small relative to body, partially withdrawn into prothorax, roughly quadrate (dorsal view) with posterior margins curvy, thick (lateral view); width (across eyes) ~0.73 mm, width (across top of mesal epicranial marks) ~0.54 mm, length (dorsum) ~0.56 mm, depth (midregion) ~0.55 mm. Anterior margin of head convex; mesal margin of labrum extending slightly beyond cranium, not protruding. All primary cephalic setae present, denticulate, stemming from large, brown bases (Fig. 4A, 4B). [On our specimen, both S12 are broken and S10 is missing (probably lost), but the setal base is present.] Vx setae either missing or well hidden beneath cervical fold/prothorax; relatively large seta mesal to antennal sockets; labrum with two or three pairs of small, simple setae. Ventral margin of cranium heavily sclerotized, fused anteriorly with stipes via broad U-shaped bridge, partially fused with cardo posteriorly via another. Mentum, postmentum with ~six simple setae.

Cephalic appendages (Figs 3A–F, 4A, 4B, 5A, 5B) relatively short, stout. Mandible sharp, without teeth, with two denticulate basolateral setae; mandible length 0.43–0.47 mm, width 0.13–0.14 mm; ratio mandible length to head width = 0.59–0.64; ratio mandible length to head length (dorsal) = ~0.77:1. Antennal length ~0.29 mm, ~1/2 length of cranium; width ~0.04 mm (at widest part of pedicel); flagellum relatively stout basally, tapering distally, with very small basolateral seta, terminus with two small spurs (one lateral, one mesal), but without elongate seta, with distal subsegment ~one-fourth length of entire flagellum; pedicel broader than base of flagellum, about 1.5 times length of flagellum; scape rounded basally, retracted into large, round, sclerotized socket mesal to eye, with

single denticulate seta distolaterally. Labial palp 0.18 mm long (total), 0.05 mm wide (at tip), 0.06 mm wide (at base); basal segment undivided, middle segment divided into two distinct subsegments, terminal segment greatly reduced or lost; with two long simple setae, one short seta on basal segment, one long denticulate, two long simple setae on second segment; terminus with two short setae distolaterally, round pore mesally; palpiger with two pairs long simple setae. *Cervix* with external surface greatly reduced; membrane almost entirely withdrawn into prothorax, largely attached to distal (not ventral or lateral) margin of cranium.

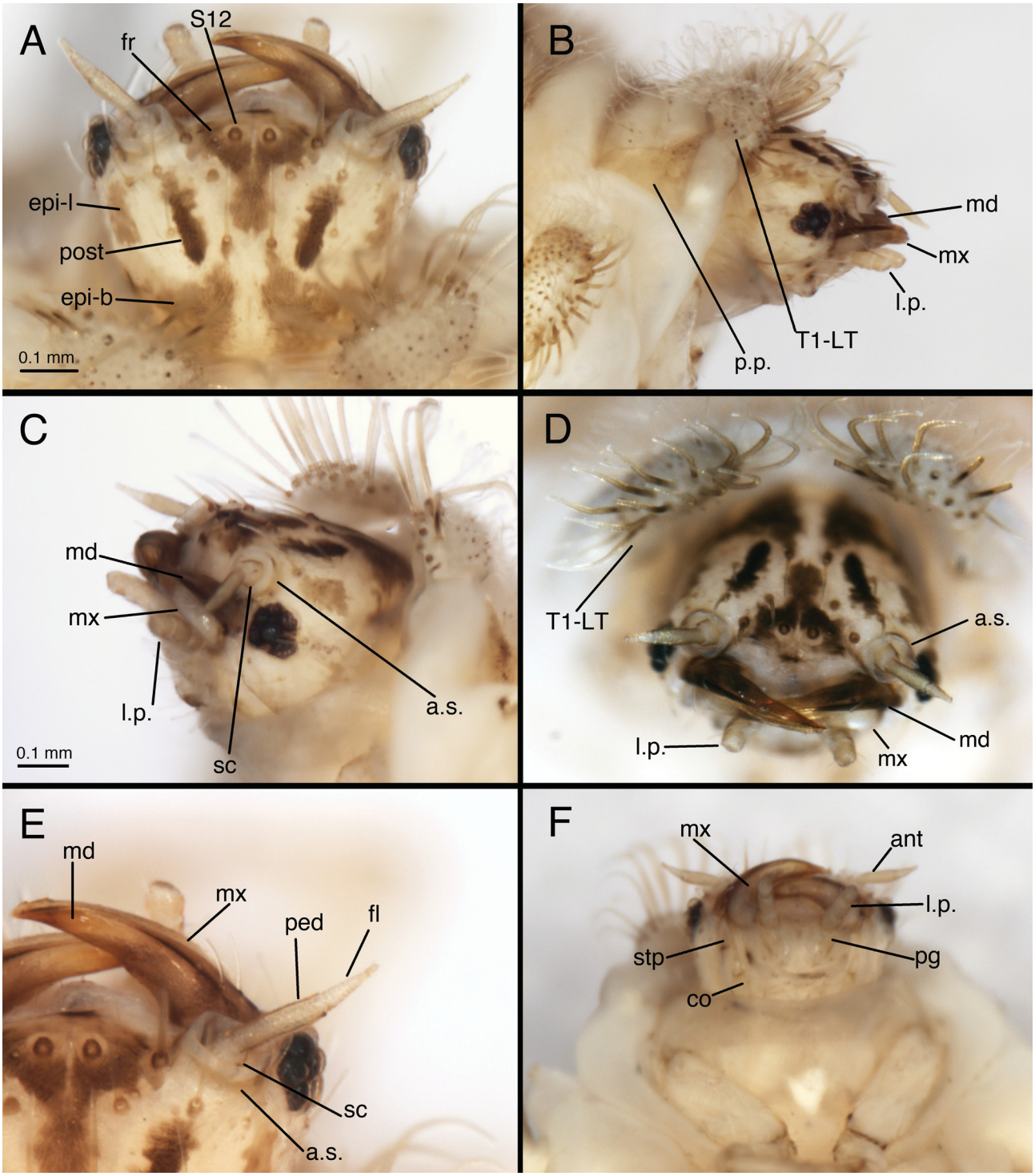

FIGURE 3. Head of *Italochrysa insignis,* third instar (Brisbane, Queensland). A. Dorsal; B. Lateral; C. Frontolateral; D. Frontal; E. Antenna; F. Ventral. Abbrevations: ant, antenna; a.s., sclerotized antennal socket; co, cardo; epi-b, base of epicranial marking; epi-l, lateral arm of epicranial marking; fl, flagellum; fr, frontal marking; l.p. labial palpus; md, mandible; mx, maxilla; ped, pedicel; pg, palpiger; post, postfrontal marking; p.p., sclerotized pronotal plate; sc, scape; stp, stipes; S12, base of twelfth primary cephalic seta; T1–LT, prothoracic lateral tubercle. (Photos, CAT)

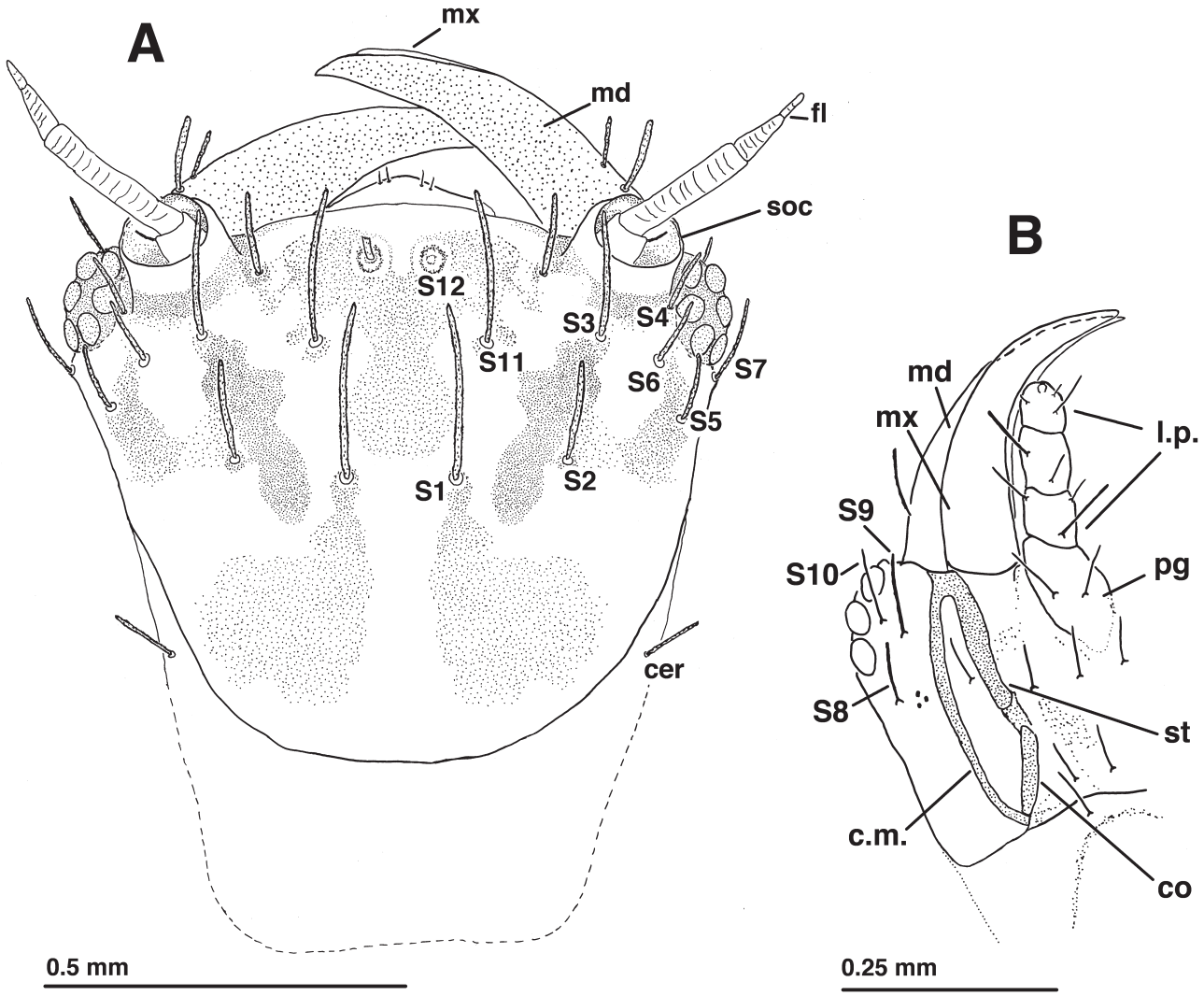

FIGURE 4. *Italochrysa insignis*, third instar (Brisbane, Queensland). A. Head, dorsal showing setation; B. Head, ventral. Abbreviations: cer, lateral seta on cervix; co, cardo; c.m., ventral margin of cranium; fl, flagellum; l.p., labial paplus; mx, maxilla; md, mandible with two basolateral setae; pg, palpiger; soc, cranial socket holding base of antenna; st, stipes; Sx, primary cephalic seta number. Note: Both S12 are broken. (Drawing, CAT)

Thorax (Figs 2A–D, 3B–D, 5A–D, 6A) with prothoracic lateral tubercles (LTs) paddle-like, consisting of broad trunk and bulbous distal lobe (dorsal view), somewhat depressed (lateral view), with dense covering of smooth-hooked setae (LS) dorsally, with apical margin bearing two rows of brown to cream-colored denticulate LS. Prothoracic LT extending forward from anterior region of pronotum, above base of head, with denticulate LS bending laterally or posterolaterally. Mesothoracic, metathoracic LTs more rounded dorsally, positioned ventrolaterally on nota, extending laterally, away from body, with denticulate LS mainly bending foreward. Legs relatively short (compared with those of, e.g., Chrysopini), with mostly short, denticulate setae, except longer on tarsus, distally on tibia.

Prothorax (T1) (Figs 2B, 2C, 3B–D, 5A, 5B, 6A) bearing LTs anterolaterally, pronotal plate dorsally; pronotal plate large, quadrate (dorsal view), tan, apparently sclerotized, with Sc1 embedded laterally; Sc1 slightly darker brown than surrounding integument, large, extending along entire lateral margin of pronotal plate anteriorly to base of LT; Sc2 not identified; dorsum with two rows of smooth-hooked setae — ~5 pairs in mesal row, ~7 pairs in posterior row [primary setae not identified].

Mesothorax (T2) (Figs 2A–C, 5A–C) consisting of three folds: Anterior fold large, surrounding base and sides of pronotum, cream-colored, with very few setae—all simple; spiracle arising laterally from large, brown tubercle, with elongate, cylindrical atrium. Second fold narrow, fusiform—not reaching lateral margin of body, bearing irregular, transverse row of smooth-hooked setae. Posterior fold large, bearing LT laterally, immediately posterior to spiracle, with dense field of smooth-hooked setae across dorsum anteriorly, with very few setae—all simple—posteriorly.

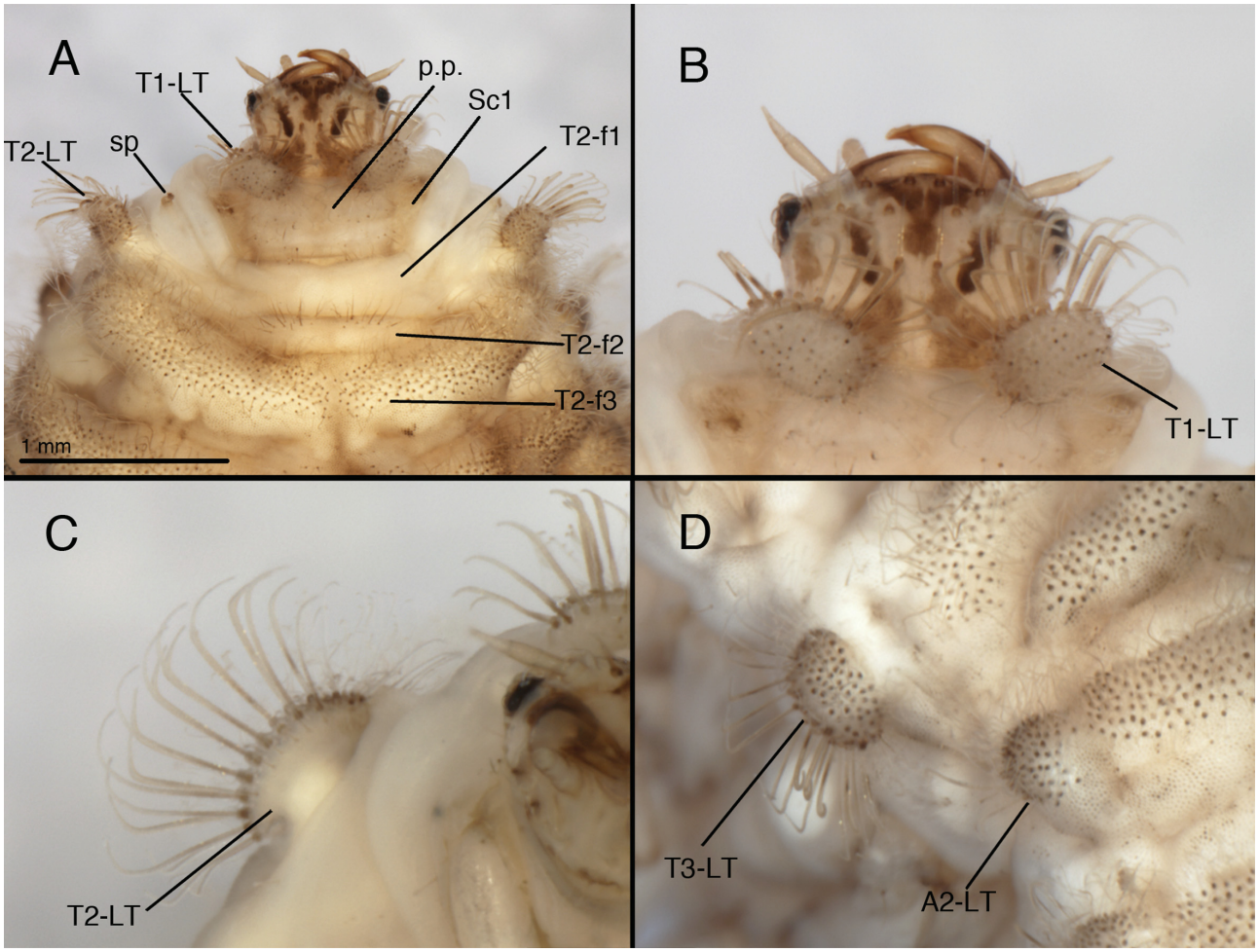

FIGURE 5. *Italochrysa insignis,* third instar (Brisbane, Queensland). A. Head, prothorax, mesothorax, dorsal; B. Prothoracic lateral tubercles, dorsal; C. Mesothoracic lateral tubercle, ventral; D. Lateral tubercles of metathorax and second abdominal segment. Abbreviations: A2-LT, lateral tubercle of second abdominal segment; p.p., pronotal plate; Sc1, first prothoracic primary sclerite; sp, spiracle; T1, prothorax; Tx-LT; thoracic segment number-lateral tubercle; T2-f1, T2-f2, T2-f3, three mesothoracic folds. (Photos, CAT)

Metathorax (T3) (Figs 2A–C, 5D) with single fold; anterior region covered with dense field of smooth-hooked setae; posterior region with very few setae; LT arising lateroventrally.

Abdomen (Figs 2A, 2D, 6B–D) extremely globose, compact; spiracles (A1–A8) circular, not raised, with simple, slightly elongate cylindrical atrium. A1: LTs, LDTs absent; dorsum with broad transverse fold having single, undivided field of dense smooth-hooked submedian setae (SMS). A2–A7: LTs broadly papilliform, each bearing several (A2–A4) to many (A5–A7) denticulate, curved or bent LS, numerous (A2–A4) to few (A5–A7) smooth-hooked setae. A2–A6: LDTs absent; dorsum of each segment with two folds; anterior fold with sparse setae laterally, dense field of setae between spiracles; posterior row with LTs laterally, broad transverse field of dense smooth-hooked SMS between LTs. A7–A10: Dorsum without smooth-hooked setae. A7: Dorsum with one to two pairs of very small setae (S1, S2) anteriorly, between spiracles; LDTs each with three large, denticulate LDS, three to four smaller denticulate LDS, two pairs of denticulate setae between LDTs. A8: Anterior region with two to three pairs of small simple setae; LTs with two to three pairs of small denticulate setae, two pairs denticulate setae between LTs, numerous spinules. A9: Segment mostly withdrawn into A8: Dorsum with several denticulate setae. A10: Segment mostly withdrawn into A9; dorsum with dense covering of microsetae. Venter (all segments) with few small simple or denticulate setae.

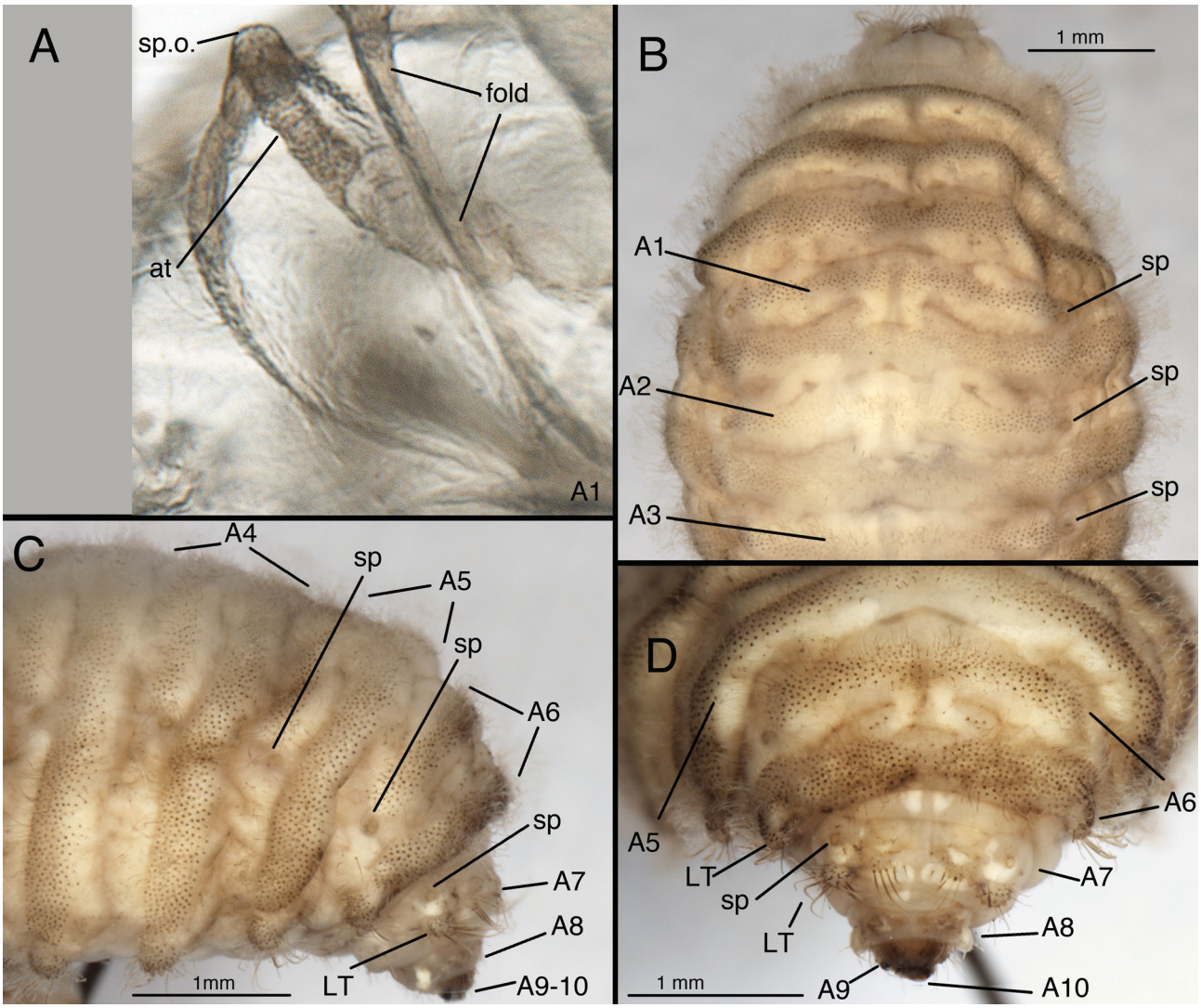

FIGURE 6. *Italochrysa insignis*, third instar (Brisbane, Queensland). A. Thoracic spiracle (cleared); B. Abdominal segments 1–3, dorsal; C. Abdominal segments 3–10, lateral; D. Abdominal segments 5–10, dorsal. Abbreviations: at, spiracular atrium; Ax, abdominal segment number; fold, mesothoracic fold; LT, lateral tubercle; sp, spiracle; sp.o., spiracular opening. (Photos, CAT)

Behavioral observations

During an approximately 30 minute period of observation, the two larvae in the nursery chamber of the *Technomyrmex* nest were in close proximity to one another and displayed no signs of conspecific aggression. Each was covered with a dense and compact, dome-like trash packet composed principally of soil and small pieces of woody or dried plant material, which extended over the head and body so that when the larva held itself close to the substrate no appendages or body parts protruded.

When the single lacewing larva was held within the rearing container, it moved freely amongst the ants [adults and brood (larvae and pupae)] and fed directly on brood. While doing so, it walked over the brood and kept its legs and appendages hidden beneath the trash packet. Initially the adult ants in the container attacked the larva but were deflected by the protective trash packet. Later they appeared aware of the larva, but were more tolerant of its presence. They seemed to be particularly agitated when the larva was in contact with the brood. After approximately 7 days the chrysopid spun a cocoon, and the ants were removed from the container.

The overall impression was that the physical barrier (the packet of debris) protected the larva from the ants; whether chemicals were involved in camouflaging or deterring the ants was not apparent. Also, it was not discernible where the chrysopid larva would normally spin its cocoon (within or outside the nest). [Note: *I. italica* larvae spin their cocoons in crevices and other such sites outside of the ant nest (Principi 1946).]

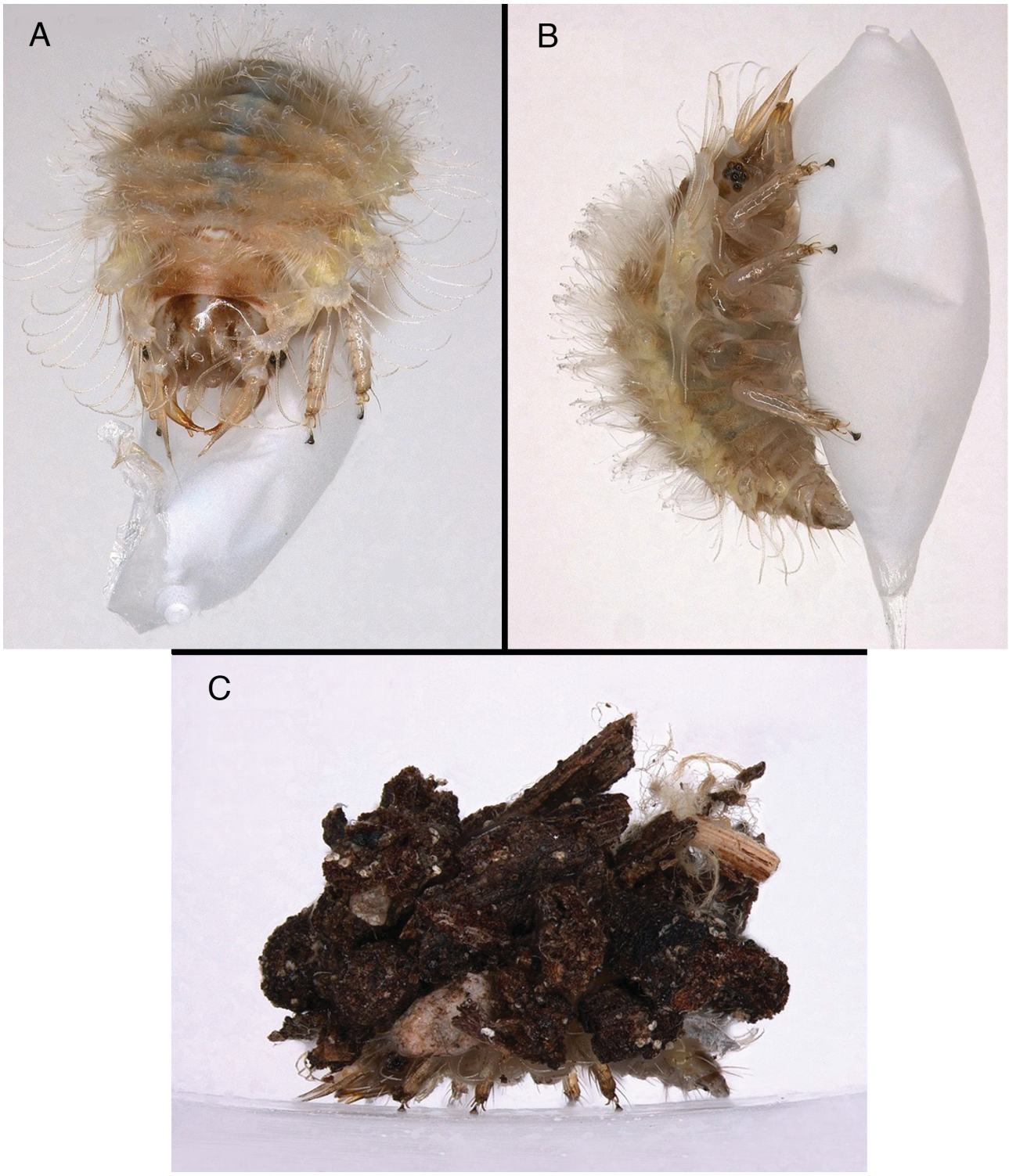

FIGURE 7. *Italochrysa italica,* first instar [Orgosolo, Nuoro, Central Sardinia, near nests of *Crematogaster scutellaris* (Olivier) in trees of *Quercus ilex* L., July 2008]. A, B. Neonate resting on eliptical egg shell, A. frontal, B. lateral (Note: head markings, body coloration, lateral tubercles, setation); C. First instar covered with debris. [Photos by R. A. Pantaleoni & C. F. Cesaroni].

Discussion

***Italochrysa* shared features.** Principi (1946), who conducted extensive observations of *I. italica* in its natural habitat, noted the extraordinary protection that the ant-feeding larvae derived from their unusual morphological, behavioral, and life-history adaptations (e.g., see Fig. 7C for the dense packet of debris that the *I. italica* first instar carries). Among the anatomical features she noted are: the small size of the head relative to the body, appendages

and terminal segments that can be withdrawn within or underneath the body, the expansion of the setal-bearing notal surface of the thorax and abdomen so that it covers the entire exposed surface of the larva, the extremely dense covering of hooked and denticulate setae that anchor a protective layer of debris on the expanded notum, the large, robust, and setose lateral tubercles that extend the debris packet over the head and outward from the body, and the presence of robust, setose laterodorsal tubercles on the seventh abdominal segment that fasten debris as a barrier to ant attack from the posterior. Our description here shows that the third instar of *I. insignis* shares all of these features (see Table 1 for details).

TABLE 1. Shared characteristics of the two described *Italochrysa* third instars [*I. italica*, *I. insignis*). See Figs. 1–4 here and also Figures II–VI in Principi (1946). At this time, among the described chrysopid larvae, the features marked with an asterisk are known only from *Italochrysa*. For comparison of belonopterygine first instars, see Tauber et al. (2006).

General		
	(1)	Setae of three types: (a) "denticulate"—robust, with blunt tip, of various sizes, some with distal 1/3rd to 1/4th sharply bent; (b) "smooth-hooked"—slender, elongate, with narrow, smooth stem, laterally flattened terminal hook; (c) simple—smooth stem with acute tip, usually small
	(2)	Body shape: robust, thick, compact; dorsum globose; venter flat
	(3)	*Thoracic (T2, T3) and abdominal (A1–A6) segments: nota expanded laterally (& LTs displaced ventrally), so setose notal surface covers entire dorsal and lateral regions
Head		
	(1)	*Cranial size: appearing relatively small; posterior section largely withdrawn into cervix and pronotum [also known from *Nacarina*, see Weber 1942]
	(2)	*Cranial shape: quadrate, broad basally, thick in lateral view
	(3)	Stemmata dark brown to black
	(4)	Antenna: *scape enclosed within deep membranous or sclerotized socket lateral to eyes; base of flagellum, pedicel relatively wide; flagellum tapering
	(5)	*Mandible robust, shorter than head length, width at base ~ 0.4–0.5x length of mandible
	(6)	*Mandibular base with two "denticulate" setae laterally
	(7)	Labium: stipes, cardo broad, robust, *oriented in longitudinal line; *palpus stout, width of middle segment about 0.4-0.6x length
	(8)	Cranial setae: *setae clustered on anterior half of cranium; posterior half largely without robust setae (except Vx setae); *all primary (dorsal and ventral) setae denticulate; some secondary setae "denticulate", others "simple", small
Thorax		
	(1)	Spiracles: borne on enlarged tubercles, with simple unraised circular opening; atrium unenlarged, with cylindrical sides
	(2)	Lateral tubercles (LTs): paddle-like or rotund, with broad trunk, bulbous distal lobe
	(3)	Laterodorsal tubercles (LDTs) absent
	(4)	*Setae on lateral tubercles (LS): distal setae "denticulate", strongly bent distally
	(5)	Legs: relatively short
	(6)	*Pronotum: with relatively few setae (simple or "smooth-hooked") [We suspect that along with the head, much of the pronotum can be withdrawn below the meso- and metathoracic nota.]
	(7)	*Mesonotum, metanotum: with dense transverse patches of "smooth-hooked" setae
Abdomen		
	(1)	A1-A8: Spiracles sessile, without distinct associated setae
	(2)	A1: LTs, LDTs absent
	(3)	A2–A6: LTs projecting laterally; LDTs absent
	(4)	A7: LTs projecting posterolaterally; LDTs present, with elongate "denticulate" setae projecting posteriorly
	(5)	A1: notum with single transverse fold bearing single large field of "smooth-hooked" submedian setae (SMS)
	(6)	A2–A6: notum with two transverse folds; anterior fold with SMS sparse laterally, dense between spiracles; posterior fold with broad dense field of SMS between LTs
	(7)	A7: with several small "simple" setae anteriorly, two pairs "denticulate" setae between LDTs
	(8)	A8–A10: segments relatively small, largely withdrawn into anterior segment(s)
	(9)	A8–A10: segments largely withdrawn into or under anterior segments; A8: with small LTs bearing small "denticulate" LS; A8–A9: *dorsum with 2–3 pairs of "denticulate" setae.

Given the numerous similarities between *I. insignis* and *I. italica* third instars, it appears that a relatively large number of characters distinguish the genus *Italochrysa*. However, we suspect that some of the shared character states for *Italochrysa* third instars listed on Table 1 will prove to be diagnostic at the tribal level, whereas others will be more useful at the generic level. For example, the third instars of the belonopterygine genus *Nacarina* Navás also appear to have a small head and stocky cephalic appendages (see illustration by Weber 1942); these features may be characteristic of the tribe Belonopterygini. However, according to Weber's illustration, the lateral tubercles and degree of setation in *Nacarina* appear to be greatly reduced compared to those of *Italochrysa*. Thus these features may be useful in distinguishing among belonopterygine genera.

Information from currently known first instar belonopterygines appears to support the above findings. Data are available for three genera, including one species of *Calochrysa* (New 1986), one species of *Vieira* (Tauber et al. 2006), and two species of *Italochrysa* (*I. insignis*: New 1983, Figs 7A–C here; *I. stigmatica*: Monserrat & Díaz-Aranda 2012). Among the above taxa, all first instars share the third-instar pattern of modification in their cephalic appendages (short, stocky mandibles, labial palpi, and antennae) and also dense thoracic and abdominal setation. In addition, the first instars express significant intergeneric variation in the lateral tubercles and setation. Only *Calochrysa* and *Italochrysa* share the modified structure of the lateral tubercles, with associated supranumerary setae (LS). In contrast, *Vieira* first instars have thoracic lateral tubercles with a 2-3-3 pattern of elongate setae (LS) that is generally typical of chrysopid larvae (Tauber et al. 2006).

Interspecific differences. Despite the numerous similarities between the Australian *I. insignis* and the European *I. italica*, the third instars of the two species also differ in some notable ways. [Note: The character states listed below are those for *I. insignis*. Those that Principi (1946) described and/or illustrated for *I. italica* are in brackets; the chestnut coloration that she described for the third instar is also visible in the first instar (Fig. 7A).]

1. Antenna:
   a. length ~one-half length of cranium (*italica* = ~0.85 length of cranium, excluding terminal bristle)
   b. scape sunken within large, sclerotized prominence (*italica* = prominence membranous)
   c. flagellum readily distinguishable from pedicel, approximately one-half the length of the pedicel (*italica* = less easily distinguished from pedicel, approximately one-fourth the length of the pedicel)
   d. distal subsegment of flagellum ~one-fourth length of entire flagellar segment (*italica* = distal subsegment very small)
   e. flagellum without elongate terminal seta (bristle), with two very small spurs (*italica* with elongate terminal bristle, one small lateral seta) [Note: it is possible that the flagella were lost from our specimen – either as a result of ant attack before collection or afterwards during preservation; however, we could find no traces of such a loss: i.e., the tips of the two antennae are bilaterally symmetrical and they show no fragments.]
2. Labial palpus:
   a. terminal segment reduced or lost (*italica* = terminal segment well developed, longer than broad)
   b. middle segment with subsegments broad, rounded (*italica* = subsegments slightly more elongate)
3. Markings/coloration (see Figs 3A, 3C–E and 4A):
   a. mandibles dark brown (*italica* = chestnut-colored)
   b. labial palpus cream-colored to light tan (*italica* = chestnut-colored)
   c. epicranial marking brown (*italica* = chestnut-colored)
   d. thoracic and abdominal setal bases brown; some dentate setae light brown basally (*italica* = all probably cream-colored)

Myrmecophily in Belonopterygini. To date, mymecophily is recorded for the two belonoperyine genera (*Italochrysa, Nacarina*) for which larvae have been observed or collected in nature. For *Italochrysa*, larvae are reported to be associated with arboreal ants that nest above ground, often under bark [for *I. italica*: *Crematogaster scutellaris* (Olivier) (Principi 1944,1946; R. Pantaleoni, personal communication); for *I. insignis*: *T. jocosus*]. The *I. insignis* larvae reported here were found within the *T. jocosus* nest. In contrast, Principi (1944, 1946) observed *I. italica* larvae snatching ant larvae and/or pupae from worker ants as they carried brood outside of the nest. She observed them only infrequently entering the nests and was uncertain how often they actually did so. In either case, the larvae of both *Italochrysa* species were protected from the ants by the physical barrier of their dense debris packets. For both species, the packets were composed largely of wood fragmens and soil particles.

In addition to the above, Principi (1946) reported two behavioral patterns that may implicate chemicals as being important in the *Italochrysa* interaction with ants. First, *I. italica* larvae frequently grasp worker ant adults with their mandibles and bring the ants into contact with their debris packets. The larvae do not appear to feed on the worker ants or to harm them; they are released. The behavior may serve to transfer scent from ants to the debris packets, thus camouflaging the larvae chemically (R. A. Pantaleoni, personal communication). Second, *I. italica* larvae were observed to follow ant trails into and out of the ant nest with precision. It appeared that they perceive the ants' trail pheromone.

In contrast to the mode of myrmecophily described above for *Italochrysa* larvae, the belonopterygine genus *Nacarina* appears to have a very different pattern. Weber (1942) described discovering *N. valida* in a nest of *Camponotus* (*Myrmothrix*) *abdominalis* (Fabricius) in South America. His report did not state that the larvae carried debris packets, and Weber's illustration of the mature larva did not depict the enlarged tubercles or large setae that are typically associated with debris-carrying larvae. Like *Italochrysa* larvae, these larvae moved freely among the ants, and they were carried by worker ants as if they were brood. These findings indicate that *N. valida* larvae within the ant nest lack the physical protection of a debris packet, and that protection from host ants is largely through chemical means. [Note: There are anecdotal and unpublished reports that the North American belonopterygine *Abachrysa* has an association with ants. There is no information on the prey associations of the remaining eleven belonoptergine genera.]

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References

Brooks, S.J. (1984) A redefinition of the Italochrysini (Chrysopidae), with the description of a new genus from Nigeria. *Neuroptera International*, 3, 79–88.

Brooks, S.J. & Barnard, P.C. (1990) The green lacewings of the world: a generic review (Neuroptera: Chrysopidae). *Bulletin of the British Museum of Natural History, Entomology,* 59, 117–286.

Díaz-Aranda, L.M. & Monserrat, V.J. (1995) Aphidophagous predator diagnosis: key to genera of European chrysopid larvae (Neur.: Chrysopidae). *Entomophaga,* 40, 169–181.
http://dx.doi.org/10.1007/BF02373066

Hölzel, H. & Ohm, P. (2003) Six new Afrotropical *Italochrysa* species, with taxonomic notes on other species of the genus (Neuroptera: Chrysopidae). *Entomofauna,* 24, 9–27.

Monserrat, V.J. & Díaz-Aranda, L.M. (2012) Los estadios larvarios de los crisópidos ibéricos (Insecta, Neuroptera, Chrysopidae), nuevos elementos sobre la morfología larvaria aplicables a la sistemática de la familia. *Graellsia,* 68, 31–158.
http://dx.doi.org/10.3989/graellsia.2012.v68.055

New, T.R. (1983) The egg and first instar of *Italochrysa insignis* (Neuroptera, Chrysopidae). *Australian Entomological Magazine*, 10, 29–32.

New, T.R. (1986) Some early stages of *Calochrysa* Banks (Neuroptera, Chrysopidae). *Australian Entomological Magazine*, 13, 11–14.

Oswald, J.D. (2013) Bibliography of the Neuropterida: a working bibliography of the literature on extant and fossil Neuroptera, Megaloptera and Raphidioptera (Insecta: Neuropterida) of the World. Version 10. Available from: http://insects.tamu.edu/research/neuropterida/neur_bibliography/bibhome.html (Accessed 8 Dec. 2013)

Principi, M.M. (1943) La *Nothochrysa italica* Rossi ed i suoi singolari costumi (Neuroptera - Chrysopidae). *Bollettino della Società Entomologica Italiana,* 75, 117–118.

Principi, M.M. (1946) Contributi allo studio dei Neurotteri Italiani. IV. *Nothochrysa italica* Rossi. *Bollettino dell'Istituto di Entomologia della Università degli Studi di Bologna,* 15, 85–102.

Rousset, A. (1966) Morphologie céphalique des larves de Planipennes (Insectes Névroptéroïdes). *Mémoires du Muséum Nationale d'Histoire Naturelle, Paris* (A), 42, 1–199.

Tauber, C.A., Tauber, M.J. & Albuquerque, G.S. (2006) *Berchmansus elegans* (Neuroptera: Chrysopidae): larval and adult characteristics and new tribal affiliation. *European Journal of Entomology,* 103, 221–231. http://dx.doi.org/10.14411/eje.2006.024

Tauber, C.A., Tauber, M.J. & Albuquerque, G.S. (2014) Debris-carrying in larval Chrysopidae: Unraveling its evolutionary history. *Annals of the Entomological Society of America,* 107, 295–314. Available from: http://esa.publisher.ingentaconnect.com/content/esa/aesa/2014/00000107/00000002/art00001 (Accessed 30 May 2014)

Weber, N.A. (1942) A neuropterous myrmecophile, *Nadiva valida* Erichs. *Psyche,* 49, 1–3. http://dx.doi.org/10.1155/1942/38909